International Journal of
Electrical Engineering and Futuristic Technology
A Peer Reviewed Journal

A D PUBLICATION

IJEEFT 01 (2017) 015-019

Application of Field Oriented Control Scheme for AC Motors

Ujash V. Vachhani[1]*, Ashish R. Patel[2]

[1]M.Tech. Electrical Engineering, BVM Engineering College, Gujarat, India

[2]Asst. Prof., Electrical Engg. Dept., BVM Engineering College, Gujarat, India

ABSTRACT: This paper presents the controlling of the AC Motor by using the 'Field Oriented Control (FOC)' method. Also the paper describes the FOC scheme and its computer simulation in MATLAB/SIMULINK®. By using FOC scheme with AC motor, we can get the high starting torque like in DC motor with all the by default advantages of AC motor, is presented here.

Keywords: AC motor; control of AC motor; field oriented control; MATLAB simulink®

1. Introduction

AC Motors are widely used in so many industries. Especially induction motors are widely used because of its advantages like, ruggedness, less requirement of maintenance, low cost & weight compared to the DC motors. It is difficult to control the induction motor and to have high stating torque like DC motors. Some research work is needed for the Induction Motor to be controlled precisely. However, the precise Induction Motor controlling is not easy to develop as Induction Motor is a complicated non-linear system and rotor variables cannot be measured directly also the physical parameters are different for different operating conditions. So the control of Induction Motor is a critical issue, especially for the applications where variable speed control is required for both fast transient response & excellent steady state performance, like Electric Vehicle. Here, we will take the example of induction motor (IM) among the all AC motors.

The Induction Motor control includes many methods. A well known method Field Oriented Control is introduced in this paper. The main focus of this paper is to develop an Field Oriented control strategy for variable speed control drive formation & studying the simulation results. In a variable speed drive, the transient performance of an Induction Motor is considered. The MATLAB/SIMULINK® software is used here.

2. Field Oriented Control for the 'Induction Motor'

'Field Oriented Control (FOC)' also known as vector control, is a variable-frequency drive (VFD) control method in which the stator currents of AC three-phase electric motor are identified by two orthogonal components. As we know, FOC is used to control AC synchronous and induction motors.

FOC was originally designed for high dynamic performance motor applications, which is use to operate very smoothly over the full speed range and generate full torque at zero speed and have high dynamic performance including fast acceleration and deceleration in the applications like Electric vehicles.

*email:ujashvachhani4592@gmail.com
Tel.: +91 9033393036

Nomenclature

IM	Induction motor
FOC	Name of parameter field oriented control
DFOC	Direct field oriented control
IFOC	Indirect field oriented control
i_{qs}, i_{ds}	Stator current d-q components
ψ_{dr}, ψ_{qr}	rotor flux linkages of d & q axis respectively
ω_e	synchronous speed at which rotating frame rotates
ω_r	rotor speed
θ_e	angle of rotating frame with respect to stationary frame

The main aim of this method is to maintain the stator field and rotor field perpendicular to each other to produce the maximum torque. So that it is possible to control, directly and separately, the Induction Motor's

torque and flux. 'Induction Motor Field oriented controlled' drive obtains every advantage of DC machines. For accurate transient and steady-state responses, the instantaneous control of individual quantities is done [1], [9].

There are two types of FOC method [9].

2.1. Direct FOC (DFOC)

Flux vector, in this method is to be measured by mounting a sensor in the air-gap, which senses the flux. Because of a sensor, the construction of motor becomes complex. So it is not widely used.

2.2. Indirect FOC (IFOC)

In this method the flux vector of the rotor is estimated by using the FOC equations.

The Phasor diagram of FOC scheme is as shown below.

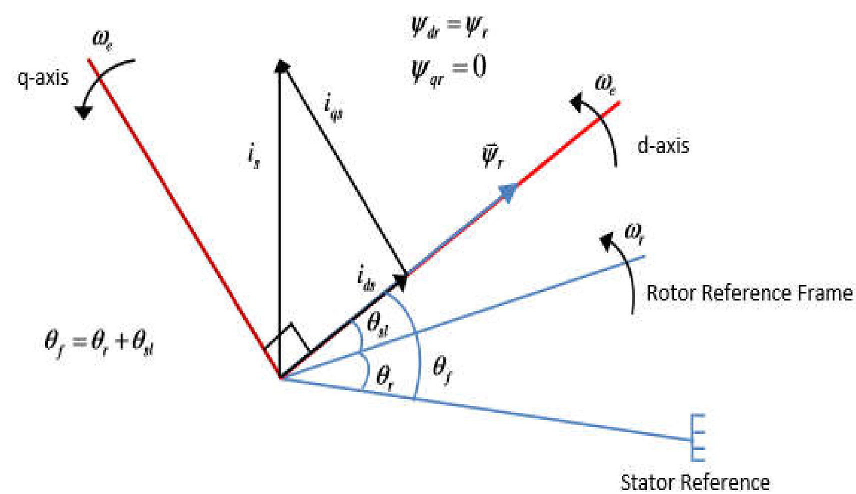

Fig: 1 Phasor diagram of FOC [9]

Here, the stator current's i_{ds} component is to be aligned with the field of rotor and the i_{qs} component is needed to be perpendicular to i_{ds}. This can only be possible by choosing 'ω_e' as a speed of the rotor flux and by locking the phase of the reference frame system such that the flux of rotor is aligned perfectly with the d-axis.

The block diagram of FOC strategy is as shown below.

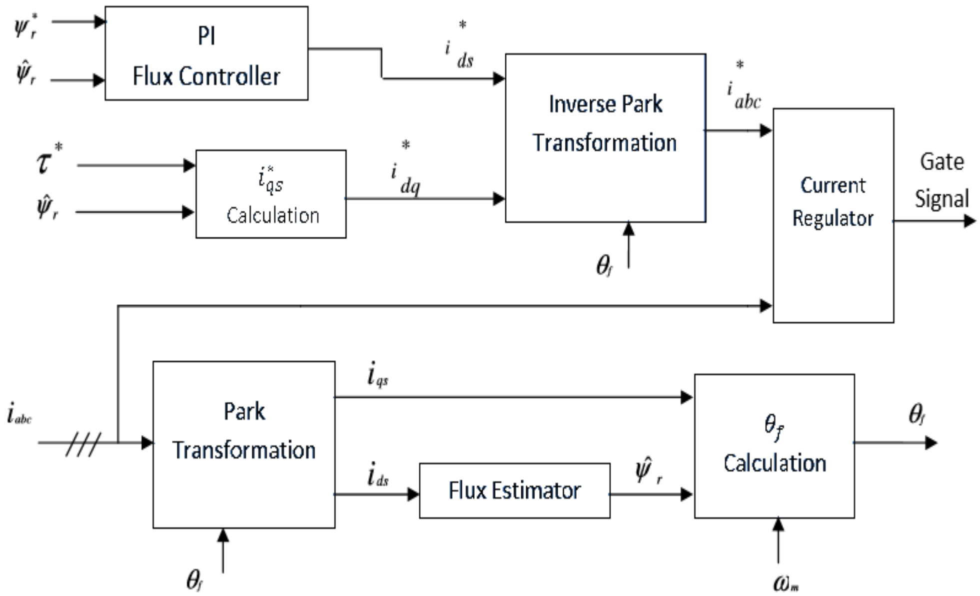

Fig: 2 Block Diagram of FOC [9]

2.3. Algorithm of FOC (IFOC)

The algorithm of FOC is summarized as described below [9].

1. The i_a, i_b and i_c stator currents are measured. If two values i_a & i_b are first measured than i_c can be easily calculated from the balanced current equation $i_a+i_b+i_c=0$.
2. All these three phase measured currents than to be transformed into two axis frame which provides two variables those are i_α and i_β in rotating two axis from the measured i_a, i_b and i_c which is known famously as 'Clarke Transformation'.
3. Magnitude of rotor flux and the orientation of it is to be calculated.
4. By using the transformation angle, which is calculated at the last iteration, the i_α and i_β are converted in the stationary two axis components i_d and i_q which is known as 'Park Transformation'.
5. By using the flux reference and its estimated flux value, the flux error signal is calculated than a PI controller is used for the calculation of i^*_d and i^*_q is to be generated by using the reference value of torque and the estimated value of flux.
6. i^*_d and i^*_q are then to be converted into a set of currents of three phase to produce i^*_a, i^*_b and i^*_c.
7. i^*_a, i^*_b, i^*_c are compared with i_a, i_b, i_c by using hysteresis comparator in order to generate gate signals for the inverter.

Now from the above diagrams the simulink model for FOC can be developed in simulink which is shown below.

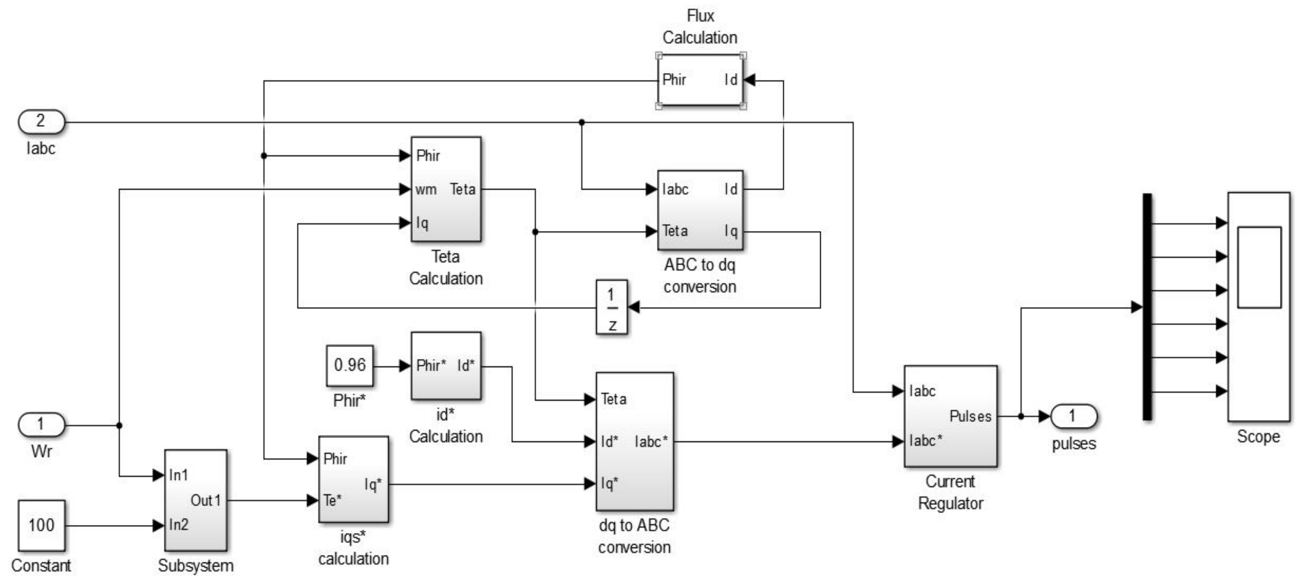

Fig: 3 Simulation model of FOC

2. Simulation Result

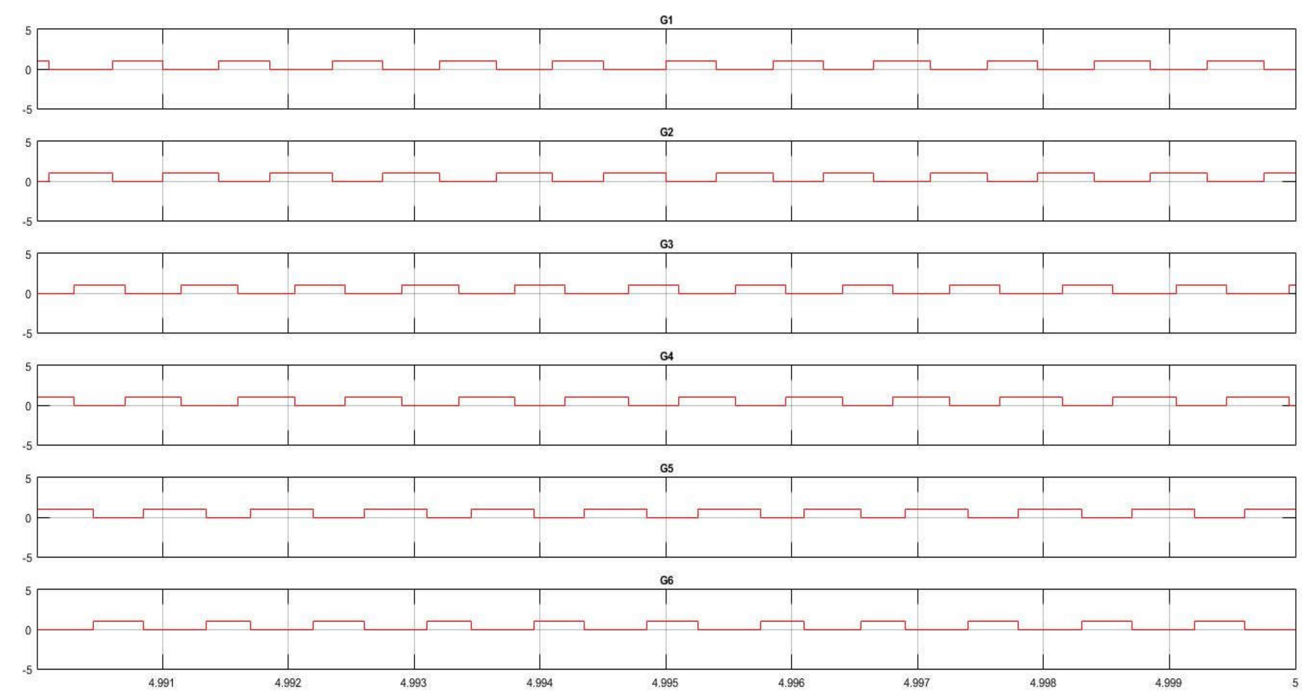

Fig: 4 Gate pulses

These are the gate pulses which we got at the output of the FOC simulation, by using the hysteresis comparator. These gate pulses are given to the inverter switches. The feedback of speed is also provided so that the operation of the switches can be controlled by controlling the gate pulses. So at the end the much needed torque and speed can be obtained as per the situation requirement by controlling the gate pulses.

Conclusion

The Field Oriented Control drive is developed in this paper. By using FOC scheme with induction motor, high starting torque can be obtained like in DC motor. The benefits of FOC are that all the advantages of DC motor can be obtained in FOC-induction motor drive, with the by default advantages of IM over DC motor, which makes the induction motor the most suitable drive for the applications where variable speed operations are necessary with fast response.

Acknowledgements

First and foremost I would like to thank the Almighty who blessed me to overcome the problems I faced while doing this work. I would also like to thank my project guide for his support towards this work. Also I would like to thank my teachers & all dear friends of mine for their help and encouragement towards this work.

Reference

Journal Papers:

[1] Popescu M., "Induction Motor Modelling for Vector Control Purposes", Helsinki University of Technology, Laboratory of Electromechanics, Report, Espoo 2000, 144 p.

[2] Anand Bellure, Dr. M. S. Aspalli, "Dynamic d-q model of Induction Motor using Simulink", IJETT – volume 24 Number 5th June, 2015.

[3] Tiecheng Sun, Jingwei Han, Deyan Gao, Sanling Xu, Ningbo Lu, "Research on Field Oriented Control system of Induction Motor based on Computer", at 2012 IEEE 7th International Power Electronics and Motion Control Conference, June 2-5, 2012, Harbin, China

[4] Burak Ozpineci, Leon M. Tolbert, "Simulink Implementation of Induction Machine Model-A Modular Approach", Oak Ridge National Labiratory, Oak Ridge

[5] Parsa Farmanzadeh, Mohammad Reza Azizian, Afshin Ebrahimi, "A Robust Conroller Design to Stabilize induction Motor Drive Operation Using IFOC Method", Sahand University of Technology, Tabriz-Iran

[6] Nisha G. K., Lakaparampil Z. V., Ushakumari S., "Torque capability improvement of sensorless FOC induction machine in field weakening for propulsion purposes" at Journal of Electrical System and Information Technology, ScienceDirect, ELSEVIER

[7] Zeina Bitar, Samih Al Jabi, "Studying the Performance of Induction Motor used in Electric Car" at The International Conference on Technologies and Materials for Renewable Energy, Environment and sustainability, TMREES14, ScienceDirect, ELSEVIER

Books:

[8] P. C. Krause, O. Wasynczuk, S. D. Sudhoff, "Analysis of Electric Machinery and Drive Systems", IEEE Press, A John Wiley & Sons, Inc. Publication Second Edition, 2002.

Theses:

[9] "Field Oriented Control", application note by Hamid Khan at RENESAS

[10] Ashish R. Patel, "Modelling and control of DFIG", M.Tech. dissertation report, IITB, 2009